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Title of the Invention

METHOD AND APPARATUS FOR PAPER MATERIAL DISCRIMINATION WITH TWO NEAR-INFRARED LIGHTS

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BACKGROUND OF THE INVENTION

The invention relates to a method and an apparatus for detecting paper material of paper and, more particularly, to a method and an apparatus for paper material discrimination of an apparatus which handles paper such as securities, bill, or the like.

As a method of detecting a paper material of paper, as disclosed in JP-A-8-180189, there is a technique made by paying attention to a peculiar structure of paper fibers which are formed in a manufacturing step of the paper. According to such a technique, a lattice-like light/dense pattern which is derived from the structure (regular pattern which is laced into paper) that is peculiar to a specific bill is fetched and data is analyzed, thereby discriminating the paper material. As disclosed in JP-A-11-139620, there is also a method of discriminating a paper material from a time that is required for conveying paper for a predetermined distance by using a principle such that friction upon conveyance differs depending on a paper material of a paper.

As disclosed in JP-A-10-232166, there is a technique regarding a discriminating method of a paper pack whereby a material of the paper containing no metal can be discriminated. According to such a

technique, by irradiating a near-infrared light onto the paper pack and specifying a wavelength at a peak of absorbance of a wavelength of the near-infrared light that is peculiar to the material, a kind of paper pack is discriminated.

The lattice-like light/dense pattern to which the attention has been paid in JP-A-8-180189 is laced into the paper which is used for the bill to identify the authentic bill. However, even in case of the same paper material, if the manufacturing steps are different, the light/dense pattern changes. There is, consequently, a problem such that the paper material cannot be precisely discriminated by one data analyzing method due to an influence by a variation of the lattice-like light/dense patterns. According to the technique of JP-A-11-139620, there is a problem such that since a degree of the friction or hardness of the paper fluctuates due to an influence by humidity, a deterioration of the paper material, or the like, such a technique can be applied only in a limited situation.

Further, according to the technique of JP-A-10-232166, in order to specify the wavelength at the peak of the absorbance, amounts of all of the reflection lights within a range from 800 nm to 2500 nm have to be obtained. There is, consequently, a problem such that a time which is required for such a purpose is too long with respect to the paper such as securities, bill, or the like in which a high speed

process is necessary.

SUMMARY OF THE INVENTION

It is an object of the invention to provide a technique for discriminating a paper material independent of a light/dense pattern which is caused by a difference of manufacturing steps. Another object of the invention is to provide a technique for discriminating a paper material of paper without being influenced by humidity or paper material. Further another object of the invention is to provide a technique for making a precise discrimination of a paper material at a high speed. Other objects will be obviously understood from the following detailed description.

According to the invention, lights of different kinds of wavelengths are irradiated onto paper and absorbances of reflected lights are measured, thereby discriminating the paper material of the paper from a difference between the absorbances. More specifically speaking, absorbances in two infrared lights of different wavelengths are obtained and the paper material is discriminated by a degree of difference between the absorbances, that is, an absorbance difference or an absorbance ratio.

Other objects, features and advantages of the invention will become apparent from the following description of the embodiments of the invention taken

in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of a measuring apparatus for discriminating a paper material of paper according to an embodiment of the invention;

Fig. 2 is flowchart for processes for paper material discrimination of the paper according to the embodiment of the invention;

Fig. 3 is a diagram showing an absorbance difference (reflecting method) of each paper;

Fig. 4 is a diagram showing an absorbance difference (transmitting method) of each paper; and

Fig. 5 is a diagram showing an absorbance difference (transmitting method correction).

DETAILED DESCRIPTION OF EMBODIMENTS

To make the present invention, spectra of near-infrared lights were analyzed with respect to a variety of many paper. Thus, a plurality of wavelengths showing absorption degree which is peculiar to each paper with respect to the absorption degree have been found out. By obtaining an absorption degree difference by a combination of the absorbances at those wavelengths and using the absorption degree difference, the paper material can be precisely discriminated at a high speed independent of a light/dense pattern caused due to a difference of manufacturing steps, and the

paper material of the paper can be discriminated without being influenced by humidity and deterioration in paper material. An embodiment of the invention will now be described hereinbelow with reference to the drawings.

According to the embodiment, the photometric operation is executed by using two kinds of lights belonging to a wavelength range between 800 nm and 2200 nm, and the paper material of the paper is discriminated by using their photometric values. In the embodiment, such a wavelength range between 800 nm and 2200 nm is referred to as a near-infrared light range.

Fig. 1 shows a measuring apparatus for realizing the invention. This measuring apparatus 1 is built in a bill discriminating apparatus, an automatic bill handling apparatus, or the like (not shown).

The measuring apparatus 1 is constructed by: a light emitting unit 2 for irradiating lights of different wavelengths; a photosensing unit 3 for receiving reflection lights obtained when the lights emitted from the light emitting unit 2 are reflected by paper; a storing unit 4 for storing a table in which paper materials of the paper and an absorbance difference of the paper materials are stored as a pair; a control unit 5 for calculating the absorbance difference from the reflected lights received by the photosensing unit 3 and discriminating the paper material with reference to the table (not shown) stored

in the storing unit 4; and a display unit 6 for displaying a discrimination result of the control unit 5.

The light emitting unit 2 can have two independent light emitting units each for generating a light of a specific wavelength width or can be also constructed so as to generate two wavelengths by a filter. It is also possible to construct the apparatus in a manner such that a plurality of different wavelengths are generated by the light emitting unit 2 and a filter for transmitting the two wavelengths is provided for the photosensing unit.

In the construction of Fig. 1, the absorbance is obtained by the reflecting method of measuring attenuation amounts of the reflected lights which are obtained when the lights for measurement are reflected by the paper. However, the absorbance can be also obtained by the transmitting method of measuring attenuation amounts of the transmitted lights which are obtained when the lights for measurement pass through the paper. One of those methods can be used. In the embodiment, in both of the transmitting method and the reflecting method, the absorbance difference or the absorbance ratio between two wavelengths is used as a parameter for discrimination.

If the two wavelengths which are used are assumed to be D1 and D2 (D1 < D2), an absorbance difference DA between two wavelengths is defined by the

following equation (1).

$$DA = LOG(I_{D2}/I_{D2,0}) - LOG(I_{D1}/I_{D1,0}) \quad \ldots (1)$$

where,

$I_{D1,0}$, $I_{D2,0}$: light intensity of the reflected light at D1 or D2 when no paper exists

I_{D1}, I_{D2}: light intensity of the reflected light at D1 or D2 when paper exists

$I_{D1,0}$, $I_{D2,0}$, I_{D1}, I_{D2}: light intensity of the transmitted light in case of using the transmitted light

Similarly, an absorbance ratio Ar between two wavelengths is defined by the following equation (2).

$$Ar = LOG(I_{D1}/I_{D1,0})/LOG(I_{D2}/I_{D2,0}) \quad \ldots (2)$$

As two kinds of lights which are used for the photometric operation, the following points have been found by analysis of the foregoing spectra. That is, it is most desirable to use wavelengths within ranges of ±30 nm around 1480 nm and 2100 nm as centers, respectively. Although wavelength bands of the lights which are used are not particularly limited, it is assumed that the lights within a range between 1 nm and 60nm can be used.

In the wavelength bands near 1480 nm and 2100 nm, an influence by a variation of absorption of each bill that is caused by the manufacturing step of the lattice-like light/dense pattern as a tint block of the bill is small. Therefore, by using the absorption degree of each paper in those wavelength bands, the

paper material itself can be discriminated independent of the lattice-like light/dense pattern. By combining characteristics of the absorption degrees to the lattice-like light/dense pattern at those wavelengths, that is, by using the absorbance difference at those wavelengths, an offset regarding the lattice-like light/dense portions of the bill is performed. Thus, the paper material can be discriminated at further high precision.

Further, in the wavelength bands near 1480 nm and 2100 nm, the absorption intensity difference at each wavelength changes in accordance with a content of amylose (containing amylopectin) in cellulose. Therefore, by obtaining an absorption degree of each bill at each of those wavelengths, the content of amylose can be determined and a material which is used for the bill can be eventually determined.

Absorption due to the absorbed moisture content appears strongly in the range between 1900 nm and 2000 nm. A change in paper material in association with deterioration (increase in absorption due to yellowing or the like) appears strongly mainly in a visible light range of 800 nm or less. Therefore, by measuring the absorption degrees at the above wavelengths, an influence by those environments and an influence by the deterioration are also reduced and more precise discrimination can be made.

A processing flow for paper material

discrimination of paper according to the embodiment will now be described with reference to Fig. 2.

First, the light emitting unit 2 irradiates two kinds of lights of different wavelengths to paper as a measurement target (step 11). Subsequently, the photosensing unit 3 receives the reflected lights from the paper (step 12). When the photosensing unit 3 receives the reflected lights, the control unit 5 measures an absorbance spectrum of each of the received reflected lights (step 13) and calculates an absorbance difference between two reflected lights (step 14). The control unit 5 discriminates the paper material of the paper with reference to the correspondence table (not shown) of the paper material and the absorbance difference stored in the storing unit (step 15).

Fig. 3 shows measurement results obtained by measuring the absorbance difference between two wavelengths by the reflecting method. As paper, the following pieces of paper are used: that is, normal copy paper (1); color copy paper A (2) and B (3); surface coated paper A (4) and B (5); delumyna paper (6); insulative kraft paper (7); filter paper (8); a bill A (9); a bill B (10); and a bill C (11). A reference numeral written in ( ) denotes the number of each paper shown on an axis of abscissa in Fig. 3.

First, a recording spectrometer in which an integrating sphere unit with a bore of 150 mm has been installed is used as a measuring apparatus. A size of

test piece of each discrimination target paper is set to about 50 square mm (however, the bills are used in their own states). (Reflection) absorbance spectra of those test pieces are measured in a wavelength range between 900 nm and 2200 nm. Absorbances at two wavelengths (1480 nm, 2100 nm) are read out from the obtained spectra and an absorbance difference is calculated by using the above equation (1). Thus, distinct differences could be confirmed in accordance with the paper materials of the paper as shown in Fig. 4.

In the experiments, the absorbance spectra have been measured in the wavelength range between 900 nm and 2200 nm, the absorbances for two different wavelengths are obtained in the measuring apparatus. As mentioned above, by using the absorbance of each paper for the infrared lights of two specific wavelengths, the high precise discrimination which is hardly influenced by a tint block of the discrimination target paper can be promptly realized by a simple construction. Further, according to the invention, two wavelengths which are effective to determine contents in amylose are used for paper material discrimination. By using such a construction, the paper material is discriminated from the contents in amylose and, further, the bill using such paper can be effectively discriminated.

At a point when the present invention has

be n made, as a speed of the conveying mechanism of the bill as a discrimination target, a speed in a range between hundreds of sheets per second and thousand and several hundreds sheets per second is required. Therefore, a similar bill discriminating speed is required. In order to make precise discrimination of the paper material at such a high speed, the technique of the embodiment is very effective.

Another embodiment of the invention will now be described. The embodiment which will be described hereinbelow relates to a technique for discriminating a paper material at high precision with respect to paper printed and colored with dye, pigment, or the like having an influence of absorption in a near-infrared range. According to a construction of the embodiment, the printed and colored paper is photometered by using three kinds of lights within a wavelength range between 800 nm and 2200 nm, and in the discrimination of the paper material of the paper, an influence on photometric values by the print or the like performed on the surface of the paper is corrected.

Among the lights which are used for those three kinds of photometric operations, two wavelengths on the long wavelength side become the photometric wavelengths for discriminating the paper material itself of the paper. As such two wavelengths, it is desirable to use wavelengths in ranges within ±30 nm around 1480 nm and 2100 nm as centers, respectively, in

a manner similar to the foregoing embodiment. Likewise, wavelength bands of the lights which are used are not particularly limited but a wavelength band between 1 nm and 60 nm can be used, respectively.

The third photometric wavelength as a feature of the embodiment is used for correcting an influence on a photometric value with regard to paper printed and colored with dye, pigment, or the like having an influence of absorption in the near-infrared range. That is, when a reflected light amount is attenuated due to an influence by various dyes and stains, a base of the absorbance spectrum increases. In such a state, since an absorption peak decreases relatively, it is necessary to correct an absolute value by using a reference value.

As a third photometric wavelength mentioned above, in a range between 900 nm and 1000 nm, it is suitable to select a wavelength band in a range between 1 nm and 60 nm. With respect to the wavelength band, it is desirable to use the wavelength band similar to that of the infrared lights for obtaining the reflection degree as mentioned above.

As a photometric method, in a manner similar to the foregoing embodiment, either the reflecting method or the transmitting method can be used without any problem. For both of the transmitting method and the reflecting method, the absorbance difference between the two wavelengths which is expressed by the

equation (1) or the absorbance ratio which is expressed by the equation (2) can be used as a parameter for discrimination.

A measuring apparatus which is used in the embodiment is similar to that shown in Fig. 1 and its processing flow is also similar to that shown in Fig. 2. The embodiment 2 differs from the embodiment 1 with respect to a point such that a portion for executing the correcting process of the photometric value by using the light of the third photometric wavelength with regard to the printed and colored paper is the control unit 5.

The correcting process uses the following equations.

$\Delta I_R = I_1 - I_2$ ... (3)

$I(New)_1/I_1C(Used) = C$ ... (4)

Correction value $\Delta I_R' = \Delta I_R/C$ ... (5)

In this case, the absorbance difference between two wavelengths is measured in a manner similar to Fig. 4. Although the absorbances have been derived by using the transmitting method, unlike the case of Fig. 4, a measuring apparatus and a size of each test piece are similar to those upon measurement of Fig. 4. As paper, the following pieces of paper are used: that is, normal copy paper (1); color copy paper A (2) and B (3); surface coated paper A (4) and B (5); delumyna paper (6); insulative kraft paper (7); filter paper (8); a bill A (9); a bill B (10); and a bill C (11).

Fig. 4 shows the absorbance difference (obtained by the transmitting method) of each paper. As shown in Fig. 4, the difference according to the paper material of the paper could be confirmed. However, the test pieces in which the absorbance differences are close although there are absorbance differences exist as shown in the test pieces of Nos. 6, 9, and 11. Therefore, by correcting the above (transmission) absorbance into the absorbance per unit thickness, results as shown in Fig. 5 are obtained. The distinct differences according to the paper material of the paper could be confirmed. As mentioned above, the thickness correction is suitable for paper material discrimination of the paper of different thicknesses.

It should be further understood by those skilled in the art that the foregoing description has been made on embodiments of the invention and that various changes and modifications may be made in the invention without departing from the spirit of the invention and the scope of the appended claims.